AERODYNAMICS OF AFTERMARKET REAR SPOILER

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Report is submitted in partial fulfillment
of the requirements for the award of the degree of
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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive

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STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Int the Name of Allah, The Most Beneficent,, The Most Merciful

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ABSTRACT

Performance, handling, safety, and comfort of a car are significantly affected by its aerodynamic properties. Getting high power under the hood is not enough to judge the performance of the car. Aerodynamic properties must be considered for the purpose of studying the drag and stability performance of a car. In order to improve car aerodynamic drag and its stability, an aerodynamic device is needed such as rear spoiler. Rear spoiler is an aerodynamic device that functions to slow down and collect air, causing it to stagnate. This rear placing device creates an area of high pressure to replace the usual low pressure over the trunk resulting increasing stability. The objective of this study is to investigate the effects of aftermarket rear spoiler to car aerodynamics drag and stability. Several rear spoilers design is attached at rear part of base line model. Both BLM model and rear spoiler models are built in CAD software. The CAD data then, either with or without rear spoiler are analyze in CFD software to estimate the drag and lift force which is acting on the car. Force, drag and lift coefficient values will be determined in order to study their effect to drag and stability. Some limitations occurred due to the complexity of the design. From the result, rear spoiler can help to reduce drag, by creating high pressure at the back.

ABSTRAK

Prestasi, kawalan, keselamatan dan keselesaan sesebuah kenderaan banyak dipengaruhi oleh ciri-ciri aerodinamik kendereaan tersebut. Prestasi sesebuah kereta tidak dapat dinilai melalui keupayaan enjin kereta sahaja. Ciri-ciri aerodinamik pada kereta amat penting sebagai keperluan untuk kajian prestasi kereta dari segi daya tujah dan kestabilan kereta. Bagi meningkatkan keupayaan tujahan aerodinamik kereta dan keseimbangannya, radas aerodinamik diperlukan sebagai contoh ’spoiler’ belakang. ’Spoiler’ belakang adalah satu radas aerodinamik yang mana berfungsi sebagai memperlahankan aliran udara menyebabkan ia tidak mengalir. Radas yang dipasang pada bahagian belakang kereta ini akan menyebabkan terbentuknya satu kawasan yang bertekanan tinggi, menggantikan kawasan tersebut yang kebiasaannya bertekanan rendah, seterusnya meningkatkan kestabilan kereta. Objektif projek ini ialah untuk mengkaji kesan penggunaan ’spoiler’ belakang terhadap daya tujah aerodinamik kereta dan keseimbangannya. Beberapa reka bentuk ’spoiler’ belakang akan dipasang pada bahagian belakang model asas kereta. Model-model ini akan dibina terlebih dahulu dalam perisian CAD. Model-model ini kemudiannya, sama ada dengan atau tanpa ’spoiler’ belakang akan dianalisis dalam perisian CFD untuk menafsirkan daya tujah dan daya angkat yang bertindak pada badan kereta tersebut. Daripada daya-daya tersebut, pemalar daya tujah dan pemalar daya angkat akan ditentukan kerana melalui pemalar-pemalar ini, kesan daya tujah dan daya angkat dapat terhadap kereta dapat diketahui. Dari keputusan, satu kesimpulan boleh dibuat mengenai ’spoiler’ belakang boleh membantu dalam mengurangkan daya tujah pada kereta dengan menghasilkan kawasan yang bertekanan tinggi pada belakang kereta.

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LIST OF SYMBOLS

p	Pressure
ρ	Air density
v	Vehicle's speed
dF_x	Net x-component of force
dF_y	Net y-component of force
dA	Small element of surface area
τ_w	Wall shear stress
D	Drag
L	Lift
D_A	Aerodynamic drag force
C_D	Drag coefficient
A	Frontal area
L_A	Aerodynamic lift force
C_L	Lift coefficient
T_r	Air temperature
P_r	Ambient pressure
z_s	Height of spoiler

LIST OF ABBREVIATIONS

CAD	Computer-aided design
CFD	Computational fluid dynamic
3-D	Three dimensional
Re	Reynolds number
Ma	Mach number
Fr	Froude number
ε/l	Relative roughness
BLM	Base-line model

CHAPTER 1

INTRODUCTION

1.1 PROJECT INTRODUCTION

Nowadays the everyday cars are changed by their owners to make the look sportier. Having more power under the hood leads to higher speeds for which the aerodynamic properties of the car given by the designer are not enough to offer the required down force and handling. The performance, handling, safety, and comfort of an automobile are significantly affected by its aerodynamic properties. Extra parts are added to the body like rear spoilers, lower front and rear bumpers, air dams and many more aerodynamics aids as to direct the airflow in different way and offer greater drag reduction to the car and at the same time enhance the stability. In case of that, many aerodynamics aids are sold in market mostly rear spoiler. Rear spoiler is a component to increase down force for vehicle especially passenger car. It is an aerodynamic device that design to ‘spoil’ unfavorable air movement across a car body. Main fixing location is at rear portion, depends on shape of the rear portion either the car is square back, notchback or fastback because not all rear spoiler can be fix at any type of rear portion of a car. However spoiler also can be attached to front/rear bumper as air dam. Rear spoiler contributed some major aerodynamics factor which is lift and drag. The reduction of drag force can save fuel; moreover spoiler also can be used to control stability at cornering. Besides can reduce drag and reduce rear-axle lift, rear spoiler also can reduce dirt on the rear surface.

1.2 PROBLEM STATEMENT

When a driver drives his or her car in high speed condition, especially at highway which is speed limit 110 km/h, the car has high tendency to lift over. This is possible to happen because as the higher pressure air in front of the windshield travels over the windshield; it accelerates, causing the pressure to drop. This lower pressure literally lifts on the car's roof as the air passes over it. Worse still, once the air makes its way to rear window, the notch created by the window dropping down to the trunk leaves a vacuum or lower pressure space that the air is not able to fill properly. The flow is said to detach and the resulting lower pressure creates lift that then acts upon the surface area of the trunk. To reduce lift that acted on the rear trunk, a rear spoiler can attach on it to create more high pressure. Spoilers are used primarily on sedan-type cars. They act like barriers to air flow, in order to build up higher air pressure in front of the spoiler. This is useful, because as mentioned previously, a sedan car tends to become "Light" in the rear end as the low pressure area above the trunk lifts the rear end of the car.

1.3 PROJECT OBJECTIVE

The objective of the project is to investigate the effects of aftermarket rear spoiler to the car aerodynamic drag and lift. The effects of rear spoiler can be determine by estimate the value of C_D (coefficient of drag) and C_L (coefficient of lift) especially when the car in high speed which above highway speed limit. Besides, the objective of this project also to ascertain advantages and disadvantages of a passenger car having rear spoiler. The differences between car with and without spoiler can be determined by compare the value of C_D and C_L of each. Several number of rear aftermarket spoiler are selected. Five models of rear spoilers will be chosen and the 3-D models will be built in CAD software according the actual dimension. The models will be analyzed in CFD software to estimate the value of C_D and C_L. From the value of C_D and C_L, which rear spoiler either reduce drag or reduce lift force, or reduce both or not can be determine.

1.4 PROJECT DESCRIPTION

An investigation on effects of rear spoiler to car aerodynamic drag and its stability will be done by estimate the value of C_D by doing some CFD analysis. Estimation of the C_D results the effects of rear spoiler to the passenger car. Since title is 'Aerodynamics of Aftermarket Rear Spoiler', so this project is more focused on rear spoilers that are already sold in market. This is because not all design of rear spoiler is suitable and fulfills car owner's need. Some design of rear spoiler will be observed and several designs will be selected to build up model in CAD software. The models will built up according its actual dimension to make sure any errors during analyzing can be avoided. After both models of spoilers and car model completed, models then will be analyzed in CFD to estimate value of drag force and lift force. From the value of both forces, the value of C_D and C_L can be estimate and the data then interpret into graph or scatter plot and also into bar chart. Analysis for base line model will done first before proceeds to next analysis. Each model is run analysis for five times, to ensure its accuracy of the results.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL AERODYNAMICS CONCEPT

2.1.1 Bernoulli's Equation

Daniel Bernoulli's equation defines the physical law upon which most aerodynamic concept exists. This equation is absolutely fundamentals to the study of airflows, and any attempt to improve the flow field around a vehicle is governed by the natural relationship between the fluid (air), speed and pressure. The Bernoulli's equation, which is can be obtained by integrating $F = ma$ (Munson, Young, Okiishi, 2006), is derived using the assumptions that (1) the air density does not change with pressure, (2) viscous effects are assumed negligible, (3) the flow is assumed to be steady, (4) the flow is assumed to be compressible and (4) the equation is applicable along a streamline (Munson, Young, Okiishi, 2006). Therefore, the formula can be applied along any point on a streamline where the relation between the local static pressure (p), density (ρ), and the velocity (v) is:

$p + \frac{1}{2} \rho v^2 + \gamma z =$ constant along streamline (Munson, 2006) [Eq. 1]

or $(p / \rho) + \frac{1}{2} v^2 =$ constant (Katz, 1995) [Eq. 2]

if it does not take into account any height term

From the equation, this indicates that an increase in pressure will cause a decrease in velocity and vice versa.

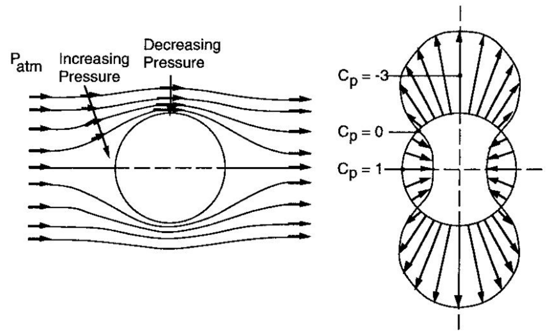


Figure 2.1: Pressure and velocity gradient in the air flow over body (Gillespie, 1992)

This moment of the air flow near the body creates a velocity distribution which in turn creates the aerodynamics loads acting on the vehicle. These loads, in general, can be divided into two (2) major contributions. The first is the shear (skin friction) force, resulting from the viscous boundary layer, which acts tangentially to the surface and contributes to drag. The second force is pressure, which acts normally (perpendicular) to the surface and contributes to both lift and drag meaning that “the vehicle downforce is really the added effect of the pressure distribution”. (Katz, 1995)

2.1.2 Drag and Lift concept

There are two basics categories of aerodynamic forces acting on the vehicle. (1) Shear stress, which an act parallel to the body surface and contributes only to drag. (2) Pressure, which acts normally (perpendicular) to the surface and is responsible for a vehicle’ lift and part of drag.

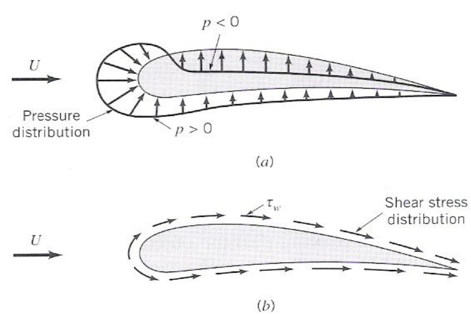


Figure 2.2: Forces from the surrounding fluid on a two-dimensional object

The resultant of the shear stress and pressure distribution can be obtained by integrating the effects of these two quantities on the body surface.

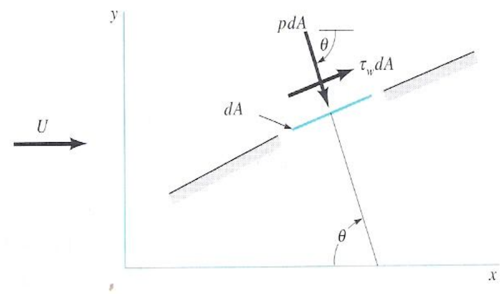


Figure 2.3: Pressure and shear forces on a small element of the surface body (Munson, 2006)

$$dF_x = (p\, dA) \cos\theta + (\tau_w\, dA) \sin\theta \qquad \text{[Eq. 3]}$$

$$dF_y = -(p\, dA) \sin\theta + (\tau_w\, dA) \cos\theta \qquad \text{[Eq. 4]}$$

Thus, the net x and y component of the force on the object are:

$$D = \int dF_x = \int p \cos\theta\, dA + \int \tau_w \sin\theta\, dA \qquad \text{[Eq. 5]}$$

$$L = \int dF_y = -\int p \sin\theta\, dA + \int \tau_w \cos\theta\, dA \text{ (Munson, 2006)} \qquad \text{[Eq. 6]}$$

The resultant force in the direction of the upstream velocity is termed the drag, D and the resultant force normal to the upstream velocity is termed of lift, L.

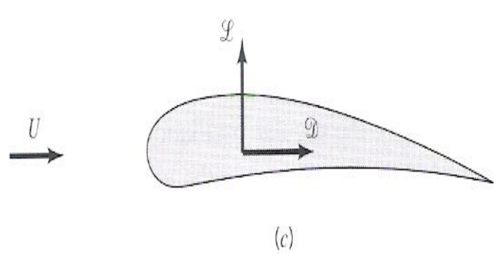


Figure 2.4: Resultant force (lift and drag) (Munson, 2006)

For some three dimensional (3-D) bodies there may also be side force that is perpendicular to the plane containing D and L. the resultant forces due to these contributions can be divided into 3 components: moment, drag and lift coefficients but here is only important in cases of strong cross winds. For this study, the cross winds is assumed negligible and only drag and lift are to be considered.

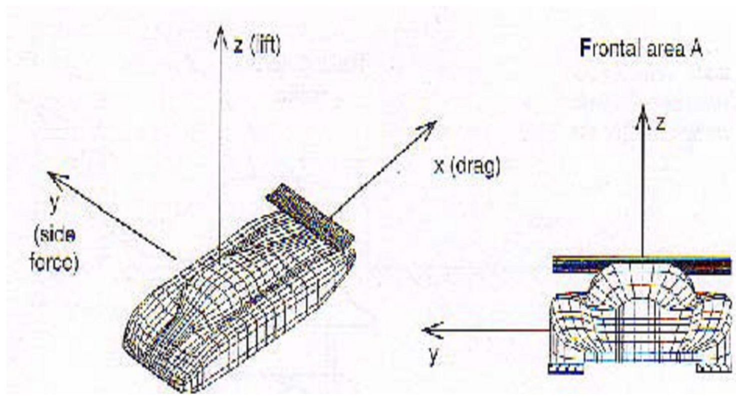


Figure 2.5: Illustrations of Lift, Drag and Moment Force Components (Katz, 1995)

2.2 AERODYNAMICS FORCES

2.2.1 Drag Force

Aerodynamics drag force is the force which opposes the forward motion of the vehicle when the vehicle is traveling. The aerodynamics drag force acts externally on the body of a vehicle. The aerodynamics drag affects the performance of a car in both speed and fuel economy as it is the power required to over come the opposing force. Because air flow over a vehicle is so complex, it is necessary to develop semi-empirical models to represent the effect. Therefore, aerodynamic drag force is characterized by:

$$D_A = ½ \rho v^2 C_D A \qquad \text{[Eq. 8]}$$

Where C_D = coefficient drag [dimensionless]

A = frontal area [m^2]

ρ = density of air [kg/m^3]

v = velocity of vehicle [m/s]

Coefficient of drag, C_D, is defined as how the aerodynamic the shape is to the incoming air. C_D is determined empirically for the car (Gillespie, 1992). It is possible to have an aerodynamic drag coefficient greater than 1 if the air is pushed outward such that the effective area of the air movement is greater than the area of object facing the air.

C_D is a function of other dimensionless parameters such as Reynold number (Re), Mach number (Ma), Froude number (Fr) and relative roughness, ε / l. That is

$$C_D = \varnothing\,(shape, Re, Ma, Fr, \varepsilon/l) \quad \text{(Munson, 2006)}$$

The frontal area, A, is the scale factor taking into account the size of the car. Because the size of a vehicle has a direct influence on drag, the drag properties of a car are sometimes characterized by the value of 'C_DA' [1]. The frontal area is slightly less than the total width of the car multiplied by its height and its measured in square meters (m^2).

The air density, ρ, is related to humidity, altitude, pressure and temperature. At standard condition, the density of air is considered 1.23 kg / m^3. Density at other conditions can be estimated for the prevailing pressure, P_r and temperature, T_r, conditions by equation:

$$\rho = 1.225\ [(Pr / 101.325)\ (288.16 / (273.16 + T_r))] \qquad \text{(Gillespie, 1992) [Eq. 9]}$$

Where P_r = atmospheric pressure in kPa

T_r = air temperature in °C

The final parameter is velocity of car, v. The speed of the vehicle is in meter per second (m/s). The term $\frac{1}{2}\rho\, v^2$ in the equation is the dynamic pressure of the air.

2.2.2 Lift force

The aerodynamic drag force is acted horizontally to the vehicle and there is another component, directed vertically, called aerodynamic lift. It reduces the frictional forces between the tires and the road, thus changing dramatically the handling characteristics of the vehicle. This will affect the handling and stability of the vehicle.

The pressure differential from the top to the bottom of vehicle causes a lift force. These forces are significant concerns in aerodynamic optimization of a vehicle because of their influence on driving stability. The force, L_A is quantified by the equation

$$L_A = \tfrac{1}{2} \rho v^2 C_L A \qquad \text{[Eq. 10]}$$

where L_A = lift force

C_L = coefficient of lift

A = frontal area

The lift force dependent on the overall shape of the vehicle. At zero wind angle, lift coefficient normally fall in the range of 0.3 to 0.5 for modern passengers car (Huco, 1998), but under crosswinds conditions the coefficient may increase dramatically reaching value of 1 or more. (Hogue, 1980)

2.2.3 Pressure distribution

Most of the lift comes from the surface pressure distribution. A typical pressure distribution on a moving car is shown in figure.

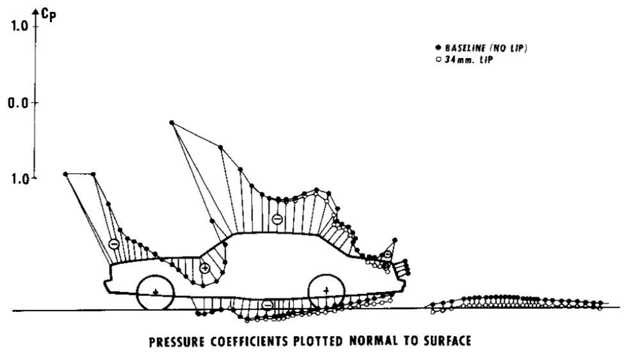


Figure 2.6: Pressure distribution along the center line of a car (Gillespie, 1992)

The distribution for the most part with simple Bernoulli equation analysis. Location with high speed flow (i.e. over the roof and hood) has low pressure while location with low speed flow (i.e. on the grill and windshield) has high pressure. It is easy to believe that the integrated effect of this pressure distribution would provide a net upward force (Munson, Young, Okiishi, 2006). This force is negative force, meaning that the force that no need to enhance the stability of a vehicle. The opposite force of upward force is downforce.

2.2.4 Downforce

Downforce is created when air moves through and over parts of the car. For example, a car wings are set at angles which force the air up and through them. For every force there is an opposite force. Therefore as the air is the air is forced upwards, it also creates a force pushing downwards. This is achieved without making the car heavier that it already is.

Downforce pushes the car into the road harder increasing the friction between the tires and the road allowing the car take corners at high speed and the driver to have more control during corner.

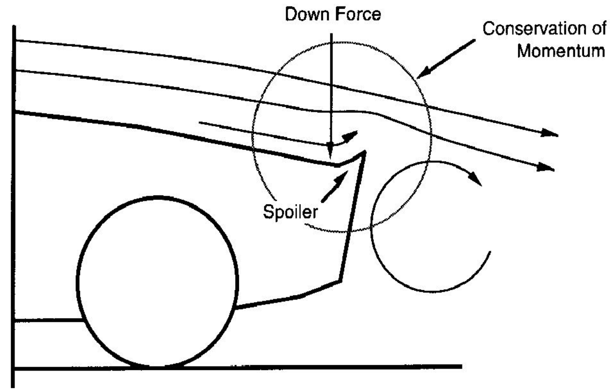


Figure 2.7: Influence of a spoiler on flow over the rear (Gillespie, 1992)

2.2.5 Drag and Lift coefficient

Drag and lift coefficient are dimensionless forms of lift and drag (Munson, Young, Okiishi, 2006). The reason for defining the drag and lift as non-dimensional coefficient is that the value of the coefficient is “independent of speed and will be related to the vehicle’s shape only”. (Katz, 1995)

The lift coefficient, C_L and drag coefficient, C_D are defined as

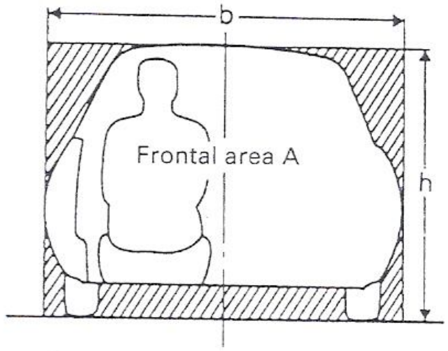
$$C_L = L_A / (1/2\ \rho\ v^2 A) \qquad \text{[Eq. 11]}$$

and

$$C_D = D_A / (½\ \rho\ v^2 A) \quad [2] \qquad \text{[Eq. 12]}$$

where D_A is the drag force and L_A is the lift force.

A is a characteristic area of the object. Typically, *A* is taken to be frontal are – “the projected area seen by a person looking toward the object from a direction parallel to upstream velocity, *v* (Munson, Young, Okiishi, 2006).



$A \approx 0.81 \cdot (b \cdot h)$

Car Class	Frontal area A m^2
mini	1.8
medium size	1.9
upper medium size	2.0
full size	2.1

Table/Figure 2.8: Frontal Area of cars (Hucho, 1998)

2.3 AERODYNAMIC DEVICE - REAR SPOILER

A spoiler is an aerodynamic device attached to an automobile rear boot whose intended design function is to ‘spoil’ unfavorable air movement across a body of a vehicle of some kind in motion. Spoilers are widely used on sedan type cars such as NASCAR stock cars. These aerodynamic aids produce down force by creating a "dam" at the rear lip of the trunk. This can result in improved vehicle stability by decreasing lift or decreasing drag that may cause unpredictable handling in a car at high speed. Spoilers are often fitted to race and high performance sports car, although they have become common on passenger vehicles as well.

Rear spoiler located on the rear deck may serve several purposes. By deflecting the air upward, the pressure on the rear deck is increase, hence creating a down force at the most advantageous point on the vehicle to reduce lift. If this modified pressure distribution is integrated in the x and y direction, the result is lower drag and lift.

A rear spoiler can have three effects. It can reduce drag, reduce rear-axle lift and reduce dirt on the rear surface. With rear spoiler also, attention first focused on drag, but increasing emphasis is now placed on negative lift.

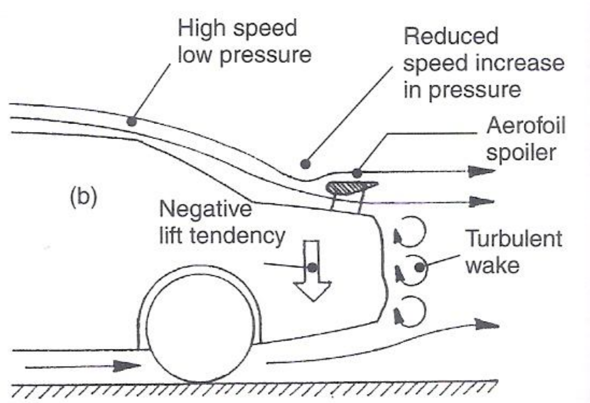


Figure 2.9: Effect of rear spoiler on lift (Heisler, 2002)

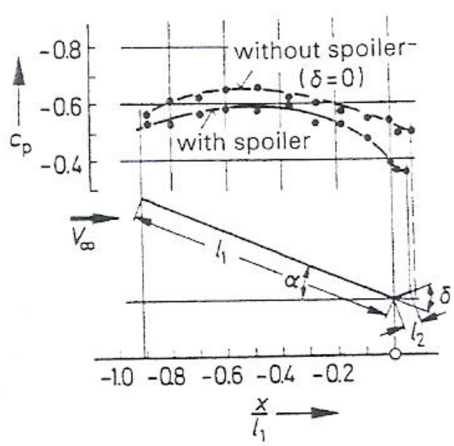


Figure 2.10: Two-dimensional flap as simulation model for a rear spoiler (Ohtani, 1972)

From the figure above, it explain about the function of a rear spoiler in terms of a flat plate under an angle of attack. By deflecting the flap, the pressure on the flat plate is increased. If this modified pressure distribution is integrated in the x and y direction, the result is lower drag and lift. Figure next shows the isobars measured for a fastback.

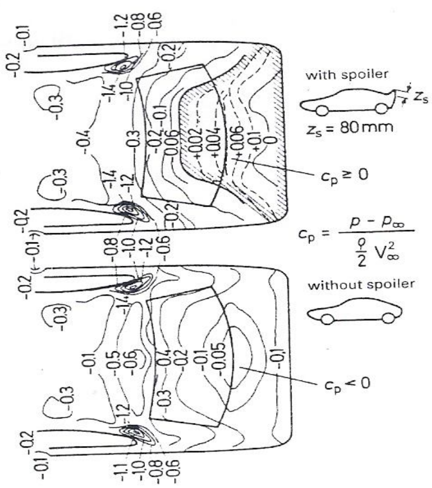


Figure 2.11: Isobars on a fastback, with and without spoiler (Ohtani, 1972)

The spoiler causes a clear rise in pressure on the rear slope in front of it. If the pressure is plotted versus the vehicle's z/h for the center cross section, the reduction in drag is obvious

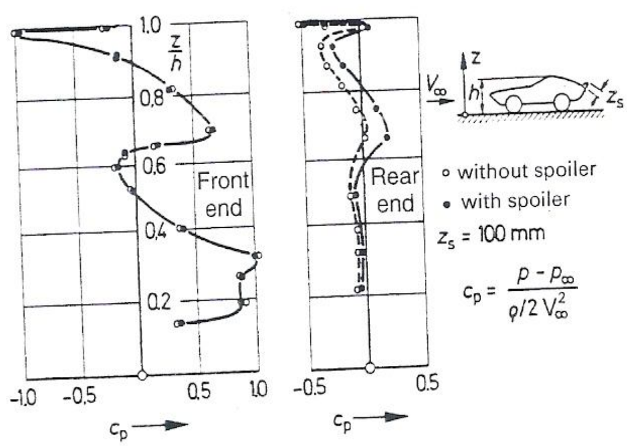


Figure 2.12: Pressure spoiler increase at the rear of a vehicle due to a rear spoiler (Ohtani, 1972)

The way in which drag and lift happened is depend on the height z_s of the spoiler. The influence on the pressure distribution is shown below. The possibility of reducing drag is comparatively low. In fact on sporty cars, and even more so on racing cars, even an increase in drag is accepted in order to ensure that the rear-axle lift gets low.

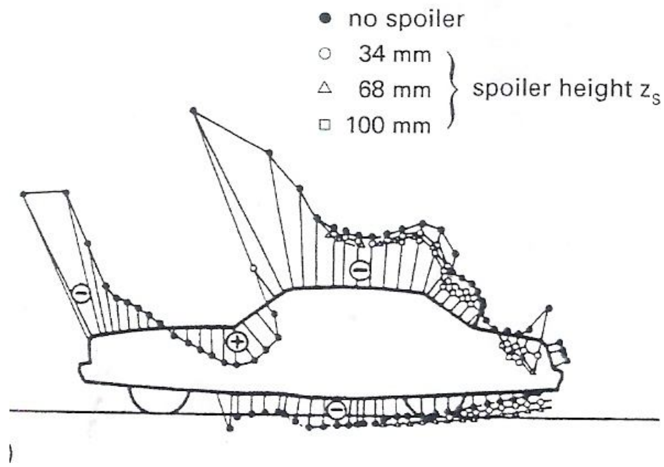


Figure 2.13: Influence of the height of a rear spoiler on pressure distribution (Schenkel, 1977)

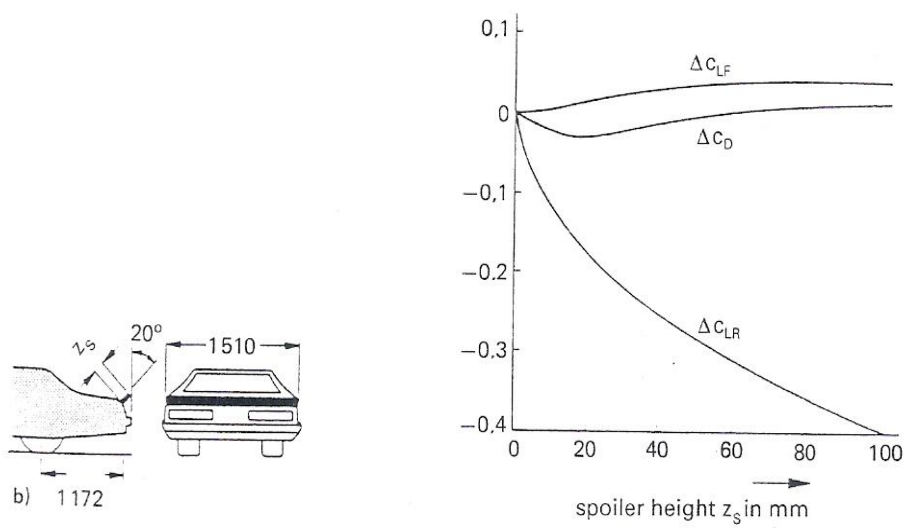


Figure 2.14: Influence of the height of a rear spoiler on lift and drag for a notchback (Schenkel, 1977)

The extended rear spoiler can increase the pressure on hatch; as a result, rear-axle lift is reduced about a third. Figure below is shows how a rear spoiler influences in reducing lift force at rear.

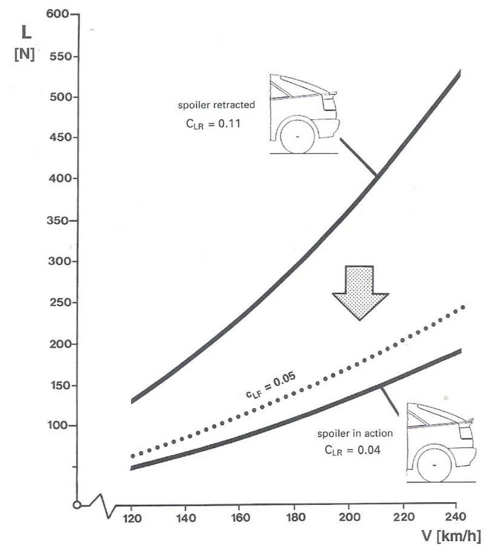


Figure 2.15: Reduction in rear-axle lift on the Volkswagen Corrado by means of a retractable rear spoiler (Schuster and Horn, 1989)

Figure 2.16 also is intended to demonstrate how a given pair of values can be achieved with quite different shapes, thereby allowing considerable freedom to design.

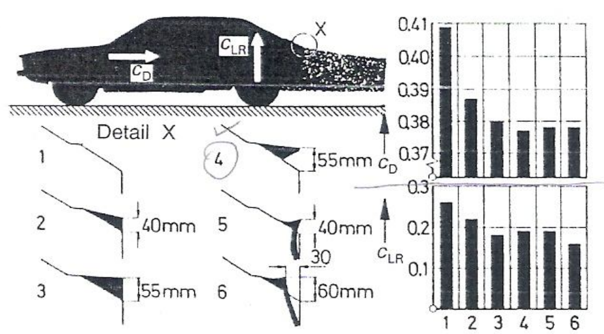


Figure 2.16: Design alternatives for a rear spoiler (Jansen, 1975)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Since this project titled "Aerodynamics of Aftermarket Rear Spoiler", a detail related literature review was done and important information was explained in details in previous chapter. Then, methods proceeding to next step will be done. This part is important to make sure that all the progresses are done step by step. Besides, it is also to ensure the project is finish by the schedule (project timeline) and the objective of the project is achieved. A survey on design of the aftermarket rear spoiler was done by surveying several spoiler designs in market that currently most used. Because there several type of rear spoiler in market, so this step to ensure that the rear spoiler that will be used is most used by car's owner. The designs then build up in CAD software and analyze in CFD software. The result of analysis will be either use or refine if needed. The result of analysis will be analyze and discuss for the next step and summary will be done to conclude the project.

3.2 SURVEYING AND OBSERVING THE DESIGN

Several design of aftermarket spoiler was surveyed and observed in market. The survey was done by searching in market and also looks out in the internet. Besides, by searching in car magazines and also by observed on-road car with rear spoiler can be done. There are many type of spoiler out there and the design must be capable and suitable with car model. This is because to minimize any errors during analyzing. May be some designs are not suit with the model. The test car model is sedan type. So, rear spoiler to attach at the rear boot must suit and fix with that kind of car design. Spoiler like deck lid or free-standing airfoil must be used, which is suitable with sedan type car. Sedan cars rear boot is known as notchback. Therefore, the spoilers that are use for squareback car and hatchback car can be ignored.

Figure 3.1: Deck lid spoiler

Figure 3.2: Several type of rear wing

3.3 MODELLING IN CAD SOFTWARE

CAE tools will be use for modeling and analyzing the models. First, the models will build up in CAD (Computer-Aided Design) software. Mostly people use CAD software to design and build up the model. For this project, SolidWorks will be use to build up the model and the model will be design according the actual dimension to make sure it can produce an approximately accurate. The design of the spoiler not just accurate in dimension, but it also must fix with the base line model that will be use. This precaution step can avoid any errors during analysis and also to make the model of spoiler is easily mate with the base line model. The base line model that will be use in this project also must build up according the actual design. The base line model used is Proton Saga 2008 and rear spoiler models that used is airfoils spoiler, touring wing, GTR wing, deck-lid spoiler, and V-man wing.

3.3.1 Base Line Model

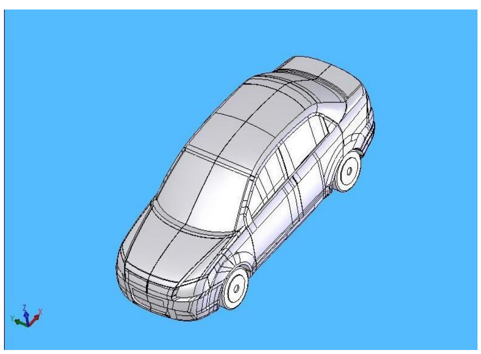


Figure 3.3: Isometric view of BLM

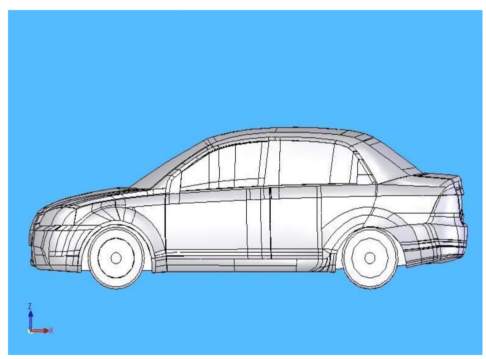


Figure 3.4: Side view of BLM

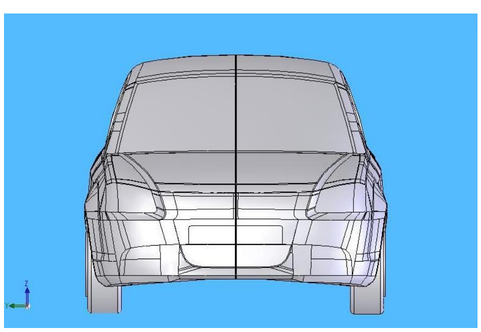


Figure 3.5: Frontal view of BLM

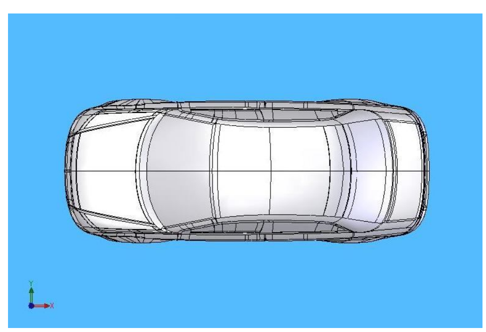


Figure 3.6: Top view of BLM

3.3.2 Rear Spoiler Model

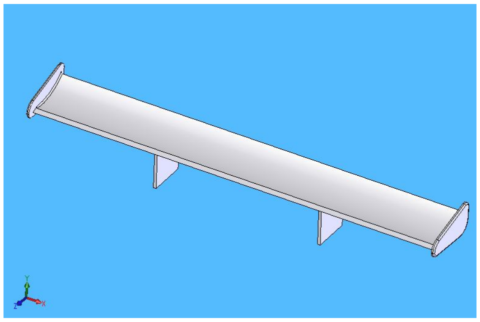


Figure 3.7: Airfoils spoiler (Spoiler 1)

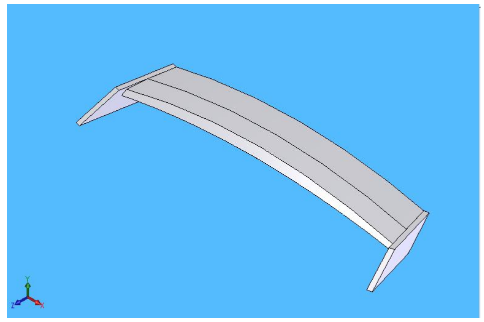


Figure 3.8: Touring wing (Spoiler 2)

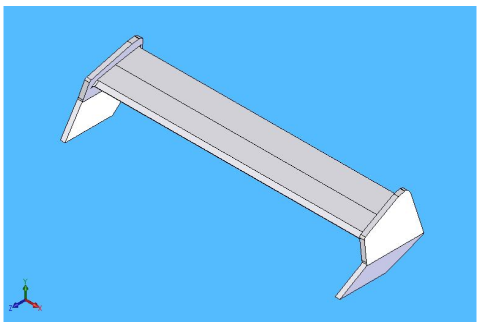


Figure 3.9: GTR wing (Spoiler 3)

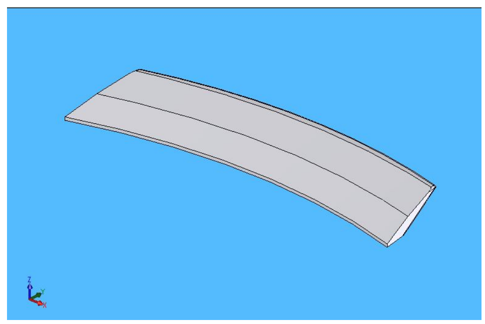


Figure 3.10: Deck lid spoiler (Spoiler 4)

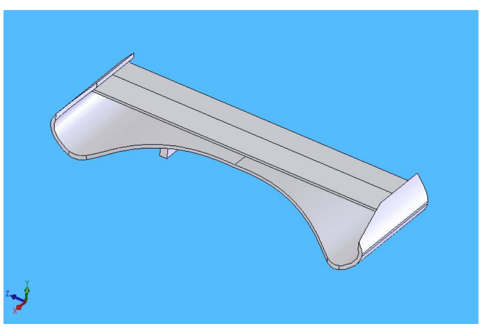


Figure 3.11: V-man wing (Spoiler 5)

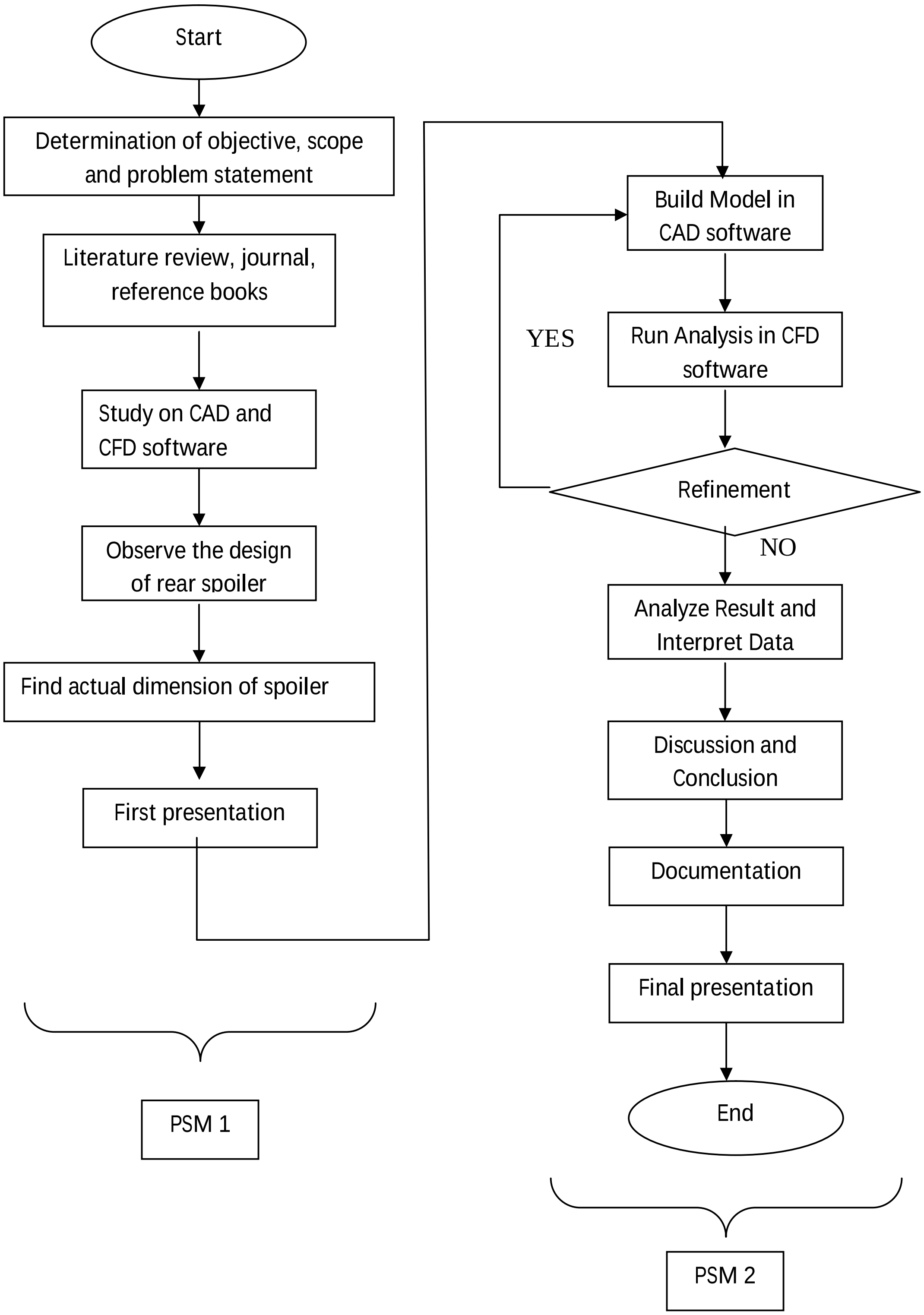
3.4 ANALYZING IN CFD SOFTWARE

During this project, COSMOSFloWorks will be use to analyze the car model with its attachment, which is the spoiler. COSMOSFloWorks is the only fluid flow analysis tool for designers fully embedded inside SolidWorks. With this software, it can analyze the solid model directly. The model that has been built up in SolidWorks then will be export into COSMOSFloWorks to analyze the model. Through this software, it can analyze parts, assemblies, subassemblies, and multibodies. Detail steps for use this software is include in its tutorial. The design will analyze, the data will interpret, the result will produce and analysis will summarize and present in form of table, graph, chart or etc.

During the analysis, some errors may be come. Some precaution steps must be notice before analyzing the model, such as the model is must properly build in SolidWorks. Besides, the result that will be got also is not follow as need. Let say that the result get from analysis is differ from the aspect result, known that the value of C_D is between 0.3 – 0.5 for passenger car, but result shown the C_D from analysis is larger than range. So, refinement is needed by modify the model and analyze again in COSMOSFloWorks.

Besides that, some limitations must be considered during analyzing the model to make sure that the results are acceptable. Ground line must be 160mm. Ground line is a distance between road surface and bottom part of the car. This distance is important to keep in constant so that the C_D and C_L are acceptable for standard sedan car. Another part that is important is the location of installment of rear spoiler. The location of base of rear spoiler must be same for all type of rear spoiler, so that the pressure acting at the back is in same region. So the location must be located at same point and the origin point (0,0) is acting as reference point.

3.5 OVERALL METHODOLOGY



CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The purpose of this chapter is to provide a review of past research efforts related to car aerodynamic drag & lift and its attachment for aerodynamics aids which is rear spoiler. A review of other relevant research studies is also provided. Substantial literature has been studied on aerodynamic drag, aerodynamic lift and influences from both and purpose of rear spoiler as one of the aerodynamic aids. The review is organized chronologically to offer insight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort. The review is detailed so that the present research effort can be properly tailored to add to the present body of literature as well as to justly the scope and direction of the present research effort.

4.2 DATA PRESENTATION

4.2.1 Table of Result

Table 4.1: BLM car without Rear Spoiler

Velocity (km/h)	Drag Force (N)	Lift Force (N)	C_D	C_L
70	153.86	51.109	0.329	0.1183
90	255.0	85.771	0.330	0.117
110	383.397	129.588	0.331	0.1153
130	536.83	182.00	0.333	0.108
150	718.946	248.474	0.334	0.096

Table 4.2: BLM car with Rear Spoiler 1 (Airfoils Spoiler)

Velocity (km/h)	Drag Force (N)	Lift Force (N)	C_D	C_L
70	147.431	49.646	0.3326	0.112
90	244.117	80.6639	0.333	0.110
110	369.157	125.973	0.334	0.115
130	512.359	172.825	0.335	0.113
150	684.323	224.034	0.336	0.110

Table 4.3: BLM car with Rear Spoiler 2 (Touring Wing)

Velocity (km/h)	Drag Force (N)	Lift Force (N)	C_D	C_L
70	144.062	49.867	0.325	0.1125
90	241.185	82.839	0.329	0.1130
110	364.775	127.397	0.333	0.1163
130	503.183	168.237	0.329	0.1100
150	670.066	216.906	0.329	0.1065

Table 4.4: BLM car with Rear Spoiler 3 (GTR Wing)

Velocity (km/h)	Drag Force (N)	Lift Force (N)	C_D	C_L
70	144.5	50.089	0.326	0.113
90	239.719	83.571	0.327	0.114
110	359.298	127.069	0.328	0.116
130	501.653	189.649	0.328	0.124
150	670.066	248.474	0.329	0.122